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# The 11–12 December 2003 storm in Southern Italy

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**Abstract.** We review an intense and heavy impact storm that occurred over Calabria, southern Italy, during the 11 and 12 December 2003. The event is traced back, at synoptic and planetary scales, up to 5 December 2003 by National Centre for Environmental Prediction/National Centre for Atmospheric Research (NCEP/NCAR) reanalysis fields and back-trajectories.

The role of tropical storm Odette is clearly shown as well as that of the Azores high. Even if non negligible water vapour sources are expected from the Mediterranean sea, unusually large precipitable water was present over the Atlantic mid-latitudes. It is shown that tropical storm Odette determined large evaporation from Atlantic Tropics and the cooperative action of synoptic scale and planetary scale pressure centres focused this humidity into a plume and conveyed it into the Mediterranean area.

## 1 Introduction

The Mediterranean region is often characterized by torrential rainfall and flash floods at different spatial and time scales (Siccardi, 1996) and several cases have been studied, discussed and reported in different countries around the basin.

Unusually intense rainfall occurred on 11–12 December 2003 over Calabria, southern Italy. Calabria climate is rather dry, yet heavy and high impact rainfall are not uncommon (Reale et al., 2001; Federico et al., 2003a, b).

Figure 1 shows Calabria topography averaged over 10 km<sup>2</sup> and a subset of raingauges used to analyze precipitation. Figure 2 reports analyzed precipitation cumulated from 23:00 UTC – 10 December 2003 to 23:00 UTC – 12 December 2003. More than 250 mm were recorded over a vast area in southern Calabria and one station reported about 660 mm in two days (more than half of the yearly total amount). Accumulated rain is greater over main peaks (mainly over Sila, Serre and Aspromonte) due to the orographic uplift and there

is a partial shielding effect of mountain ranges that leaves more precipitation over Ionian coastal areas. Precipitation fell mainly during 12 December when the storm was more active over southern Calabria. Landfalls were reported in several villages and damages to properties was extensive.

## 2 Role of the tropical cyclone Odette

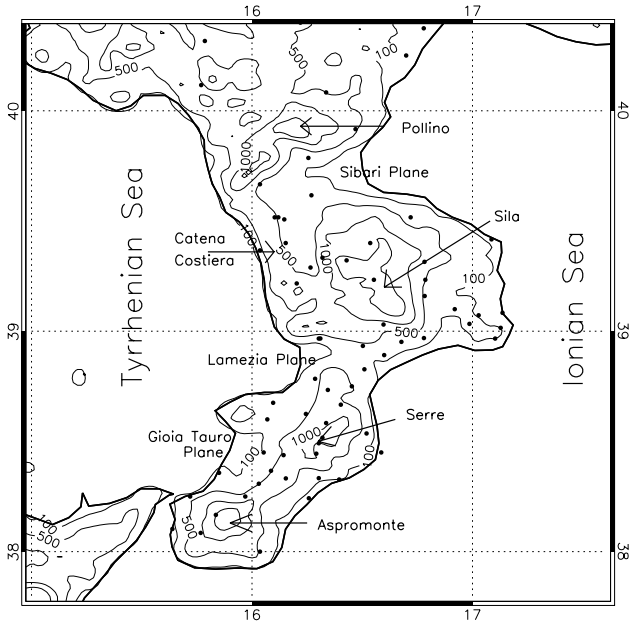
The following synoptic analysis is based on data from NCEP/NCAR reanalysis project (Kalnay et al., 1996; Kistler et al., 2001). Data are produced with a data assimilation system with a T62/28L space resolution global spectrum model and are available on a 2.5°×2.5° longitude-latitude regular grid.

In this section, synoptic conditions are traced back to 5 December to highlight the role of a tropical storm, named Odette, respect to heavy precipitation recorded in Calabria a week later.

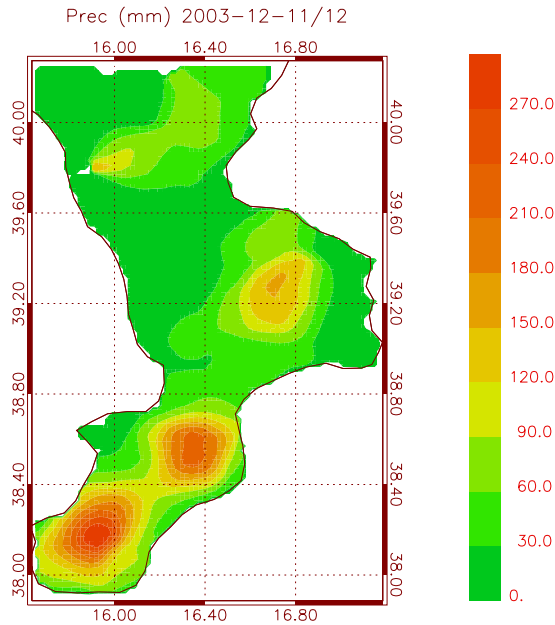
Reanalysis can provide broad information, due to their coarse horizontal resolution, of the tropical storm and following development of synoptic patterns.

Odette detailed description can be found in Franklin (2003). It was a rare December tropical storm that made landfall in the Dominican Republic and it was the first December tropical storm on record to form in the Caribbean sea.

Figure 3 shows the best track for this tropical storm. Figures 4a, b and c show, respectively, the sea level pressure, precipitable water and 850 hPa wind fields for 5, 6, 7 December 2003 over the Atlantic. The injection of huge humidity amounts into the atmosphere can be easily explained by Odette. The strong winds and convergence in the tropical storm is the responsible of large precipitable water over the Caribbean on 5 and 6 December (Figs. 4a and b). This humid air is then reorganized by a developing cyclone off the US East coasts (Fig. 4c) and then transported toward the Mediterranean basin through the cooperative action of several centres, as discussed in the next two sections.



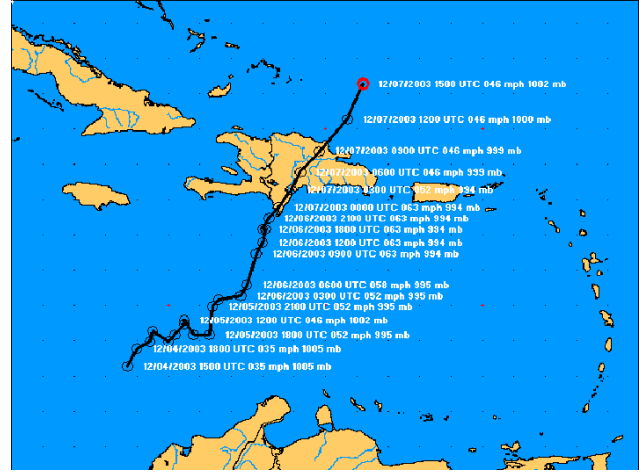
**Fig. 1.** Topography of Calabria averaged over  $10\text{ km}^2$ . Main features are also reported. Contours: 100 m, 500 m, 1000 m and 1400 m. Dots show rain gauges locations.



**Fig. 2.** Analyzed rainfall from 23:00 UTC – 10 December 2003 to 23:00 UTC – 12 December 2003. In the objective Cressman analysis we use a search radius of  $0.15^\circ$ . More than 130 rain gauges were available for the analysis.

### 3 Role of the Atlantic anticyclone

Figures 4d–f show the Atlantic sea level pressure, precipitable water and 850 hPa wind field for 8 December 2003 – 12:00 UTC, 9 December 2003 – 12:00 UTC and 10 December – 00:00 UTC, respectively.



**Fig. 3.** Tropical storm Odette best track (from Franklin 2003).

Figure 4d shows two humid plumes extending from tropical Atlantic to mid-latitudes. The westernmost one is associated with tropical storm Odette. A deep cyclone is active off the US East coast and the Azores high is well expanded over the Atlantic Ocean. This peculiar baric situation focuses large precipitable water amounts into a plume and clearly demonstrates that the origin of the water vapour is, at least partially, from tropical Atlantic.

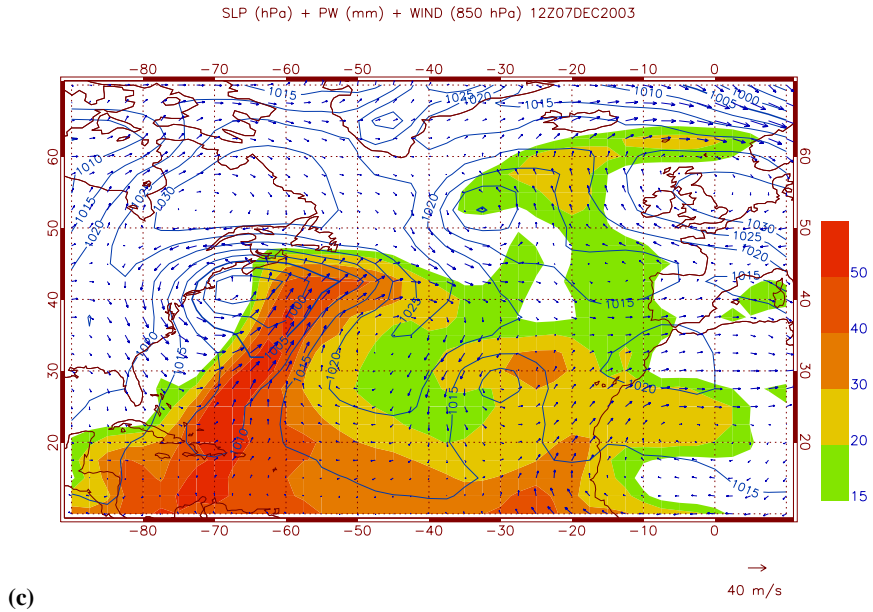
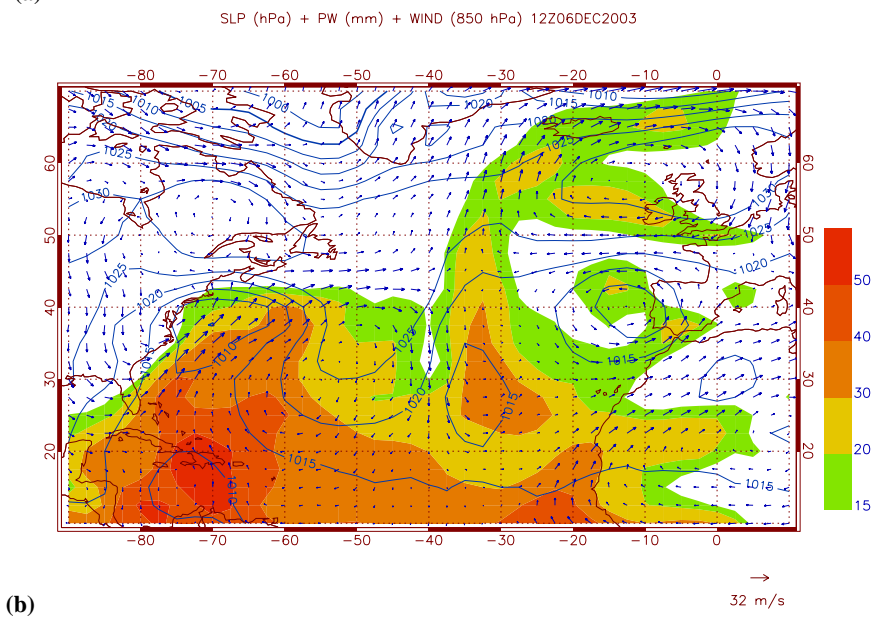
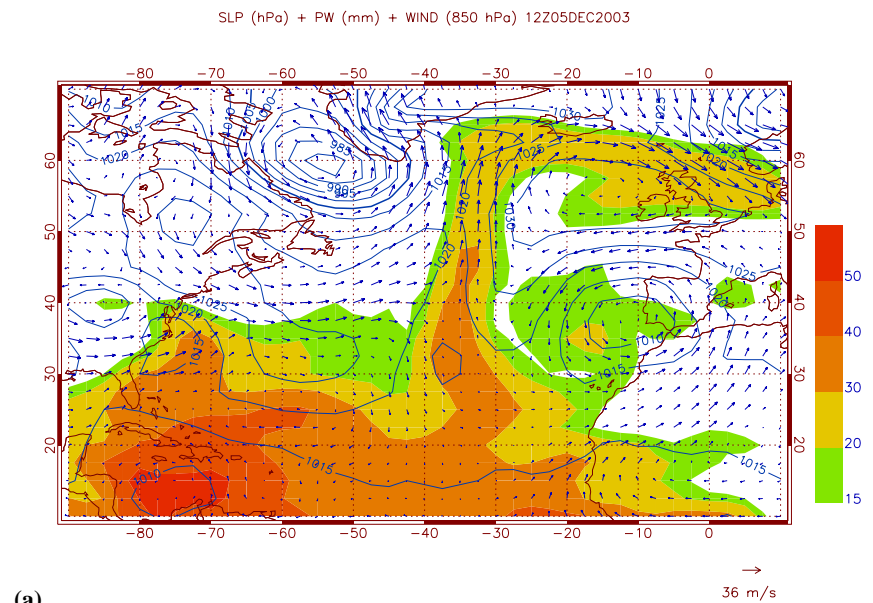
The process is still active 24 h later, as shown in Fig. 4e. The deep cyclone moved toward North-East and Azores high retracted. At the same time, a low pressure pattern with a central minimum of 1000 hPa moved from Iceland toward Iberia peninsula. This cyclone is the one that determined the 11th–12th event over Calabria. The Azores high acquired a circular shape and, by cooperative action with other pressure centres, conveys high precipitable water amounts into the Mediterranean area.

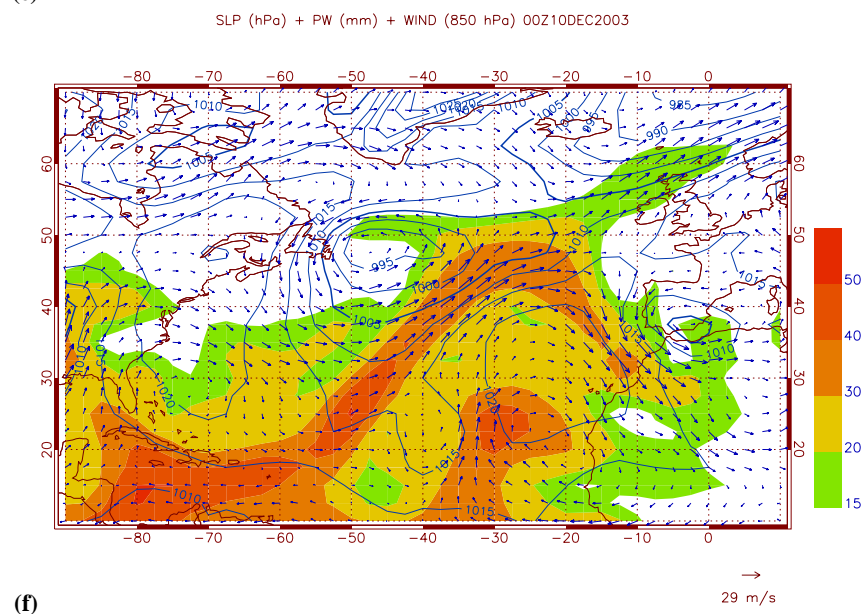
The process is still active on 00:00 UTC 10 December, as shown in Fig. 4f. At this time the Azores high retreated and moved toward North-East. The cyclone responsible of heavy precipitation over Calabria is now into the Mediterranean basin. Eighteen hours later the Azores high expanded (not shown). This shift creates the circulation conditions for interruption of air masses transport from tropical Atlantic to Mediterranean and Europe.

According to the previous analysis, planetary and synoptic scales acted together to determine the intense and heavy impact processes involved with this event.

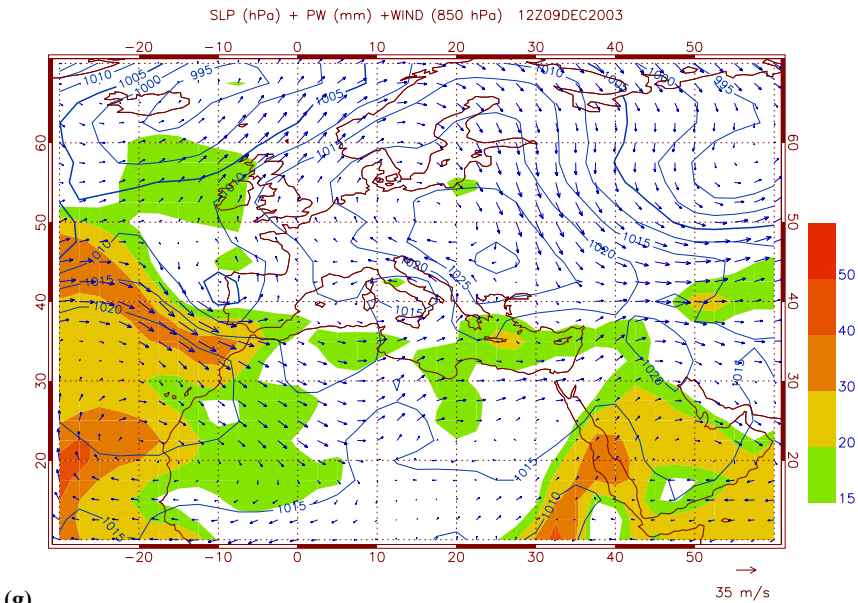
### 4 Synoptic scale analysis

Figures 4g–j show sea level pressure, 850 hPa wind field and precipitable water from 9 to 12 December 2003 – 12:00 UTC. On 9 December, the storm that produced heavy rainfall over Calabria is positioned to the West of the Iberian peninsula. This shows its Atlantic origin. Precipitable water is greater than  $30\text{ g/kg}$  over the Atlantic and it is associated with

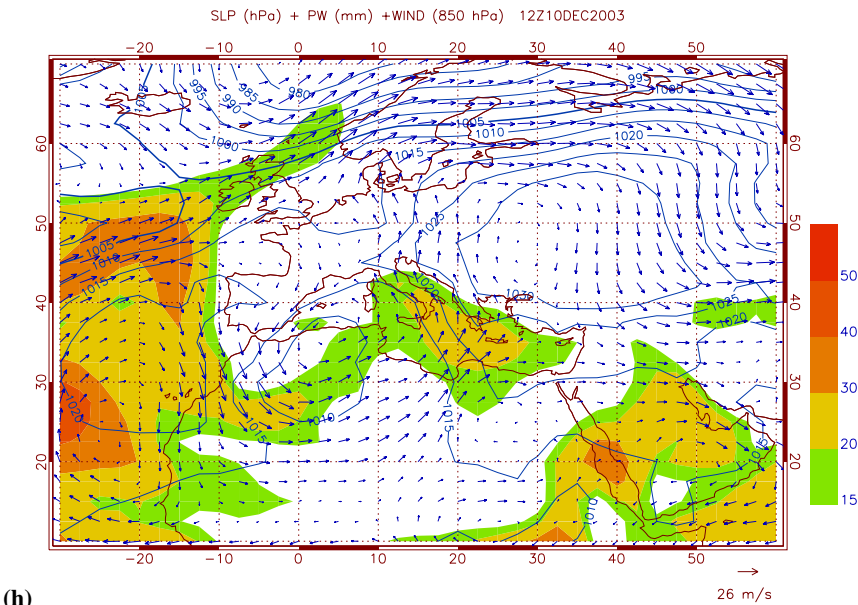




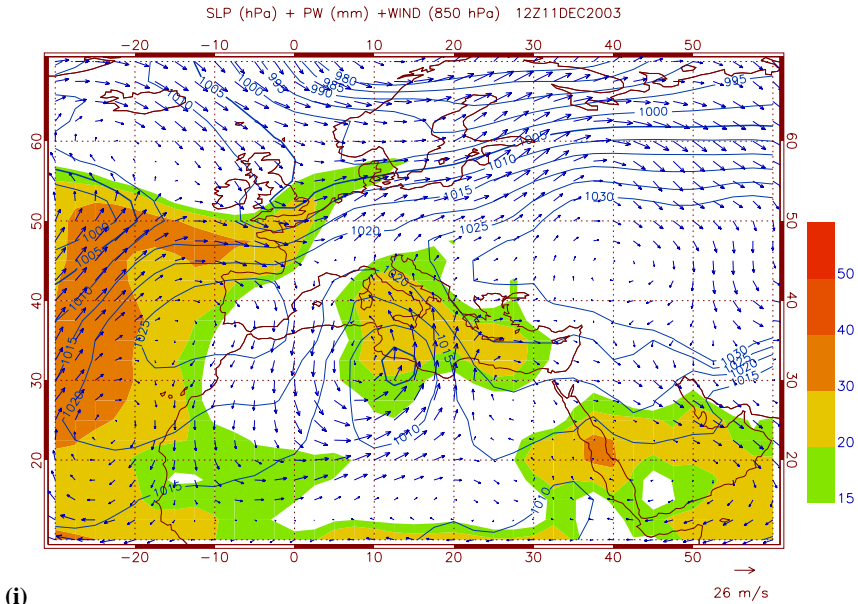




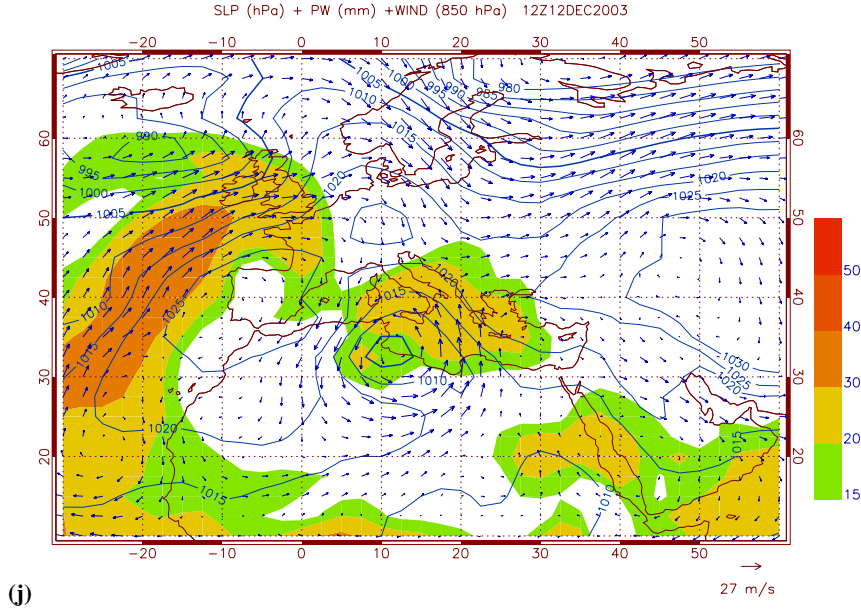
(g)



(h)



(i)



**Fig. 4.** (a): Sea level pressure (solid contours), 850 hPa wind field and total precipitable water (shaded contours) for 12:00 UTC – 5 December 2003. (b) As in (a) for 6 December 2003 – 12:00 UTC. (c) As in (a) for 7 December 2003 – 12:00 UTC. (d) As in (a) for 8 December 2003 – 12:00 UTC. (e) As in (a) for 9 December 2003 – 12:00 UTC. (f) As in (a) for 10 December 2003 – 00:00 UTC. (g) As in (a) for 12:00 UTC – 9 December 2003 and for the Mediterranean. (h) As in (g) for 10 December 2003 – 12:00 UTC. (i) As in figure (g) for 12:00 UTC – 11 December 2003. (j) As in figure (g) for 12:00 UTC – 12 December 2003.

planetary scale and synoptic scale action centres discussed in Sects. 2–3. In particular, two humid filaments of high precipitable water are evident in Fig. 4g over eastern Atlantic. First one is oriented from N–W to S–E and entered the Mediterranean basin; the second plume, located at about 30° W–20° N on 9 December – 12:00 UTC, did not play a major role during the storm and is associated with tropical storm Peter. After 24 h, Fig. 4h, the low pressure centre is over Algeria and its action is twofold. First winds over Southern Italy increase, second the plume of large water vapour of Atlantic origin is transported into the Mediterranean basin. Sustained winds over the southern Mediterranean area increase latent heat fluxes and add humidity to the overlaying air (Figs. 4i–j).

As a consequence of the storm evolution, winds cross Calabria from S–SE and air masses are rather humid. The peculiar shape of calabrian orography together with previous discussed synoptic scale processes and in particular the latent heat fluxes from the Mediterranean sea determined the heavy rainfall recorded during the event.

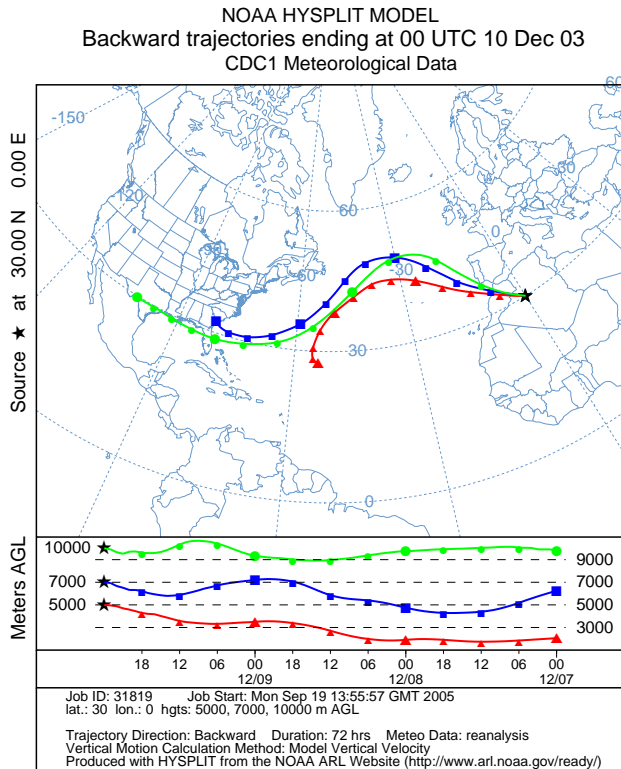
Moreover, even if we do not discuss the mesoscale of the storm in this paper, Fig. 2 shows the importance of mesoscale processes as orographic uplift operating within the favourable synoptic scale environment.

## 5 Trajectory analysis

In this section we adopt a trajectory analysis to better identify the storm air masses origin. This approach was al-

ready applied in Krichak and Alpert (1998, 2004), Stohl and James (2004), Turato et al. (2004) to determine the origin of air moisture in high impact cyclones over Europe and the Mediterranean region.

The advanced Hybrid Single Particle Integrated Trajectory system (HYSPLIT), of the NOAA/ARL, is applied for a three dimensional trajectory calculation (Draxler and Rolph, 2003). The model uses gridded meteorological data from the reanalysis project. Figure 5a shows backward trajectories for air masses ending at 40° N–15° E on 12 December 2003 – 00:00 UTC. Air masses started at 5000 m, 7000 m and 10 000 m above ground level and are representative of air movements at mid and upper troposphere. Figure 5b shows the same integrations for parcels ending at 0° E–30° N on 10 December 2003 – 00:00 UTC. These positions were chosen because they are representative of the air masses that reached Calabria during the storm most intense phase and the integration is divided in two parts to better appreciate air movements over the Atlantic and over the Mediterranean. Moreover, a rough estimate of precipitable water and sea surface pressure can be achieved comparing figures 4 and 5 and considering that marks are reported in Fig. 5 every six hours. From Figs. 5a and b it follows that air masses crossed the Atlantic Ocean during 7–10 December, then entered in the Mediterranean area and went over Calabria, transported by the synoptic scale processes discussed in the previous section.



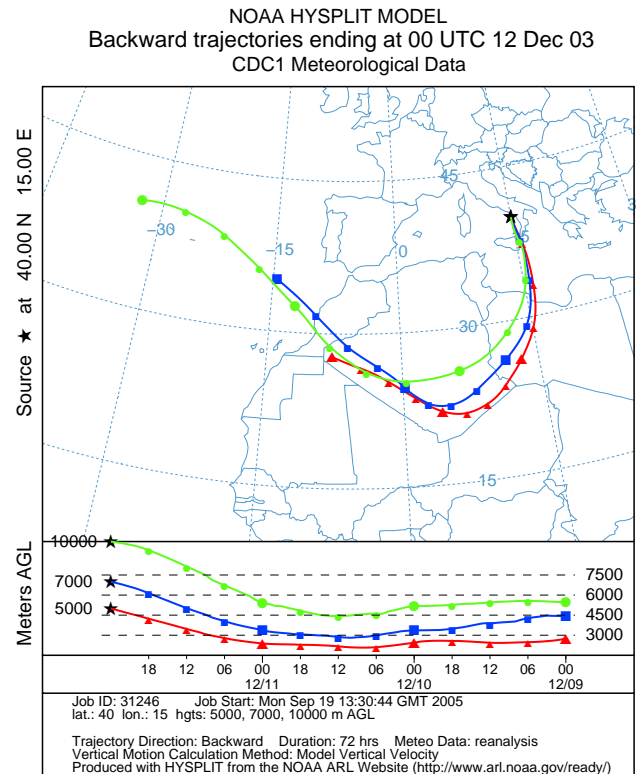
**Fig. 5a.** HYSPLIT back-trajectories ending at  $0^{\circ}$  E– $30^{\circ}$  N on 10 December 2003 – 00:00 UTC.

## 6 Conclusions

We revisit the 11–12 December 2003 storm that produced extended damages in Calabria, southern Italy, at synoptic and planetary scales using NCEP/NCAR reanalysis data and backtrajectories. Even if local scale and mesoscale processes were certainly important during the storm, our attention is focused on the large amount of precipitable water available over Atlantic mid-latitudes.

We traced back the storm up to 5 December 2003 and demonstrated that tropical storm Odette, active from 4 to 7 December 2003 in the Caribbean, injected large amount of water vapour into the atmosphere. This humidity was then reorganized and focused by the cooperative action of the a) Azores high; b) a deep cyclone developed off the US Atlantic coast; c) the cyclone that determined heavy precipitation over Calabria.

These findings have important implications for severe weather forecast over Central Mediterranean area. First, the tropical storm activity over Atlantic should be carefully monitored in order to detect potential risk situations. Second, model domains should consider in their integration area a larger portion of Atlantic Ocean than the one used nowadays. Third, more cases study must be investigated to confirm results discussed above and to better focus on key factors that could be used as precursor of severe storms.



**Fig. 5b.** As in Fig. 5a for trajectories ending at  $15^{\circ}$  E– $40^{\circ}$  N on 12 December 2003 – 00:00 UTC.

We conclude considering that hurricane activity seems to increase during last decade. For instance, during 2003, hurricane season saw the development of 16 named storm, well above the 1944–1996 average of 9.8.

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